# Physics
# Unit 7: Electricity

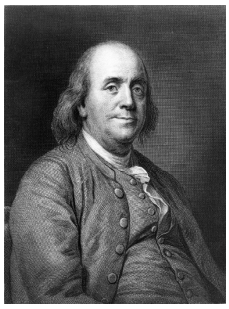
Slides

## Charge & Atoms

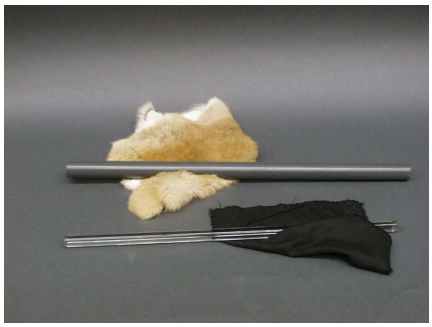
What is charge?

What are things made of?

# Early Investigations

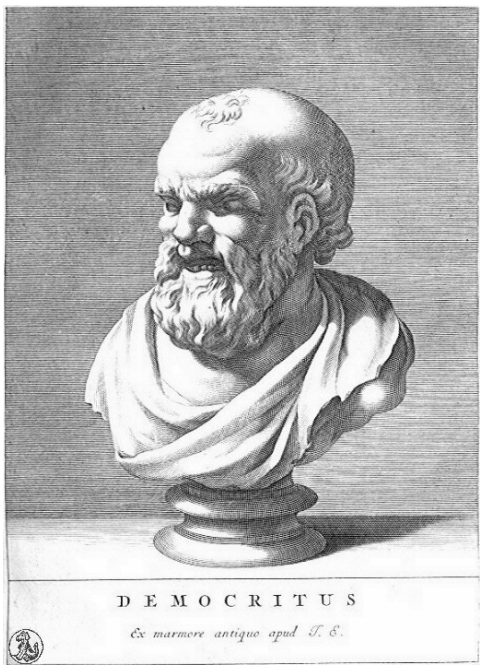


- There is a property of matter called electric charge
- Three types: positive, negative, and neutral
  - These terms came from Ben Franklin
- Charge is conserved
- Opposite charges attract
- Like charges repel



# Structure of the Atom

- Ancient Greeks (Democritus)
  - Idea of atoms

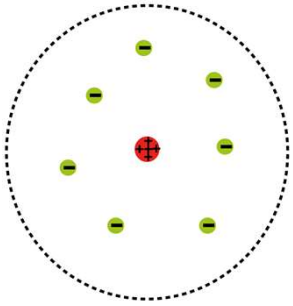


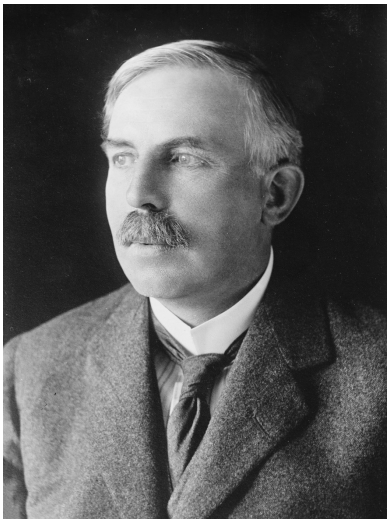
# Structure of the Atom

- J. J. Thomson
  - "Plum pudding"
  - Positive charge with little negative charges spread about

# Structure of the Atom

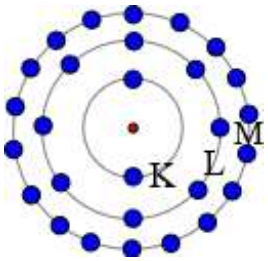
- Ernest Rutherford
  - Small, positively charged nucleus in center of atom





# Structure of the Atom

- Niels Bohr
  - Electrons orbit nucleus in circles

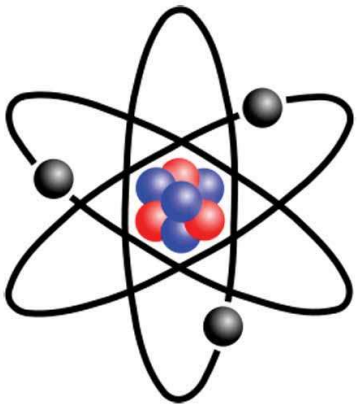



# Structure of the Atom

Protons
- Positive charge
- In the nucleus

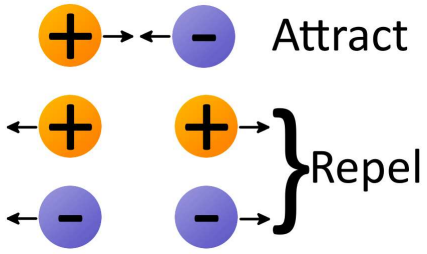
Neutrons
- Neutral charge
- In the nucleus

Electrons
- Negative charge
- The mobile charge carrier



## Law of Charges

*Opposite charges attract each other.*
*Like charges repel each other.*




- **Positive attracts negative**
- **Positive repels positive**
- **Negative repels negative**

## Law of Conservation of Charge

There is a total amount of charge in the entire Universe that does not change

- If something gains charge, it came from something else
- If something loses charge, it goes to something else

**Charge ($q$)**

- In units of **Coulombs (C)**.
- $+q$ = positive charge; $-q$ = negative charge

Fundamental charges

1 proton = $+1.61 \times 10^{-19}$ Coulombs

1 electron = $-1.61 \times 10^{-19}$ Coulombs

1 Coulomb of charge = $6.28 \times 10^{18}$ electrons

1 Coulomb of charge = $6.28 \times 10^{18}$ protons

# Charge

**ALL** objects, whether positive, negative, or neutral, have both positive (protons) and negative (electrons) charges in them. What gives an object its overall charge is whether the positive and negative charges are balanced:

- Positively charged → there are more protons than electrons
- Negatively charged → there are more electrons than protons
- Neutral → there are an equal number of protons and electrons

# Static Electricity

**Static Electricity**

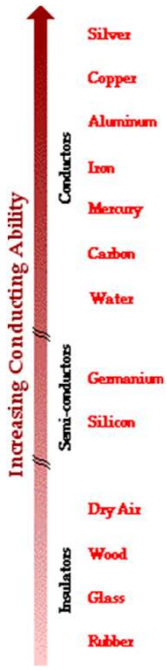
- **Stationary charges**
- **Electrons become separated from atoms when materials interact (like rubbing materials together).**
- **Surface of objects become charged**

**Electron-rich surface = negative object**
**Electron-poor surface = positive object**

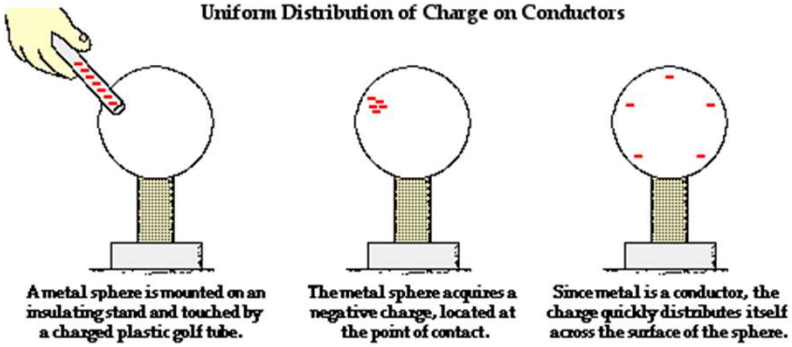
# Insulators vs. Conductors

**Insulators**: charge remains stationary on them
- Ex. Plastic, wood, glass, ceramic

**Conductors**: charge moves freely through them
- Ex. Metal, water (with dissolved minerals), graphite (pencil lead)




# Conductors




- Party-goers analogy

# Ground

A large reservoir of charge that can absorb electrons without a noticeable change in its overall charge

For example, literally, the Earth

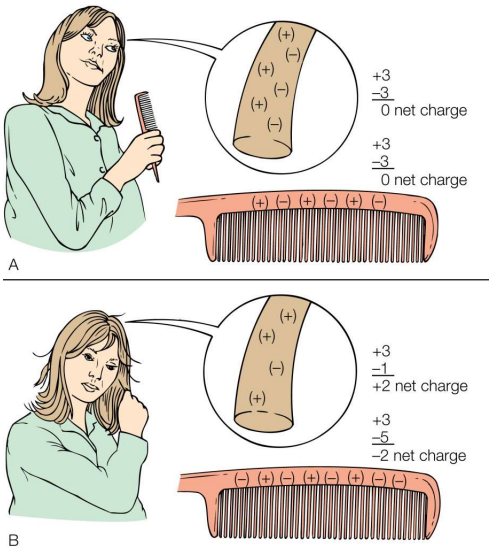
If you want to discharge static electricity, connect it to a conductor connected to the ground

**How do objects accumulate static charge?**

- **Static Electricity by Friction: rubbing objects together, one object strips electrons off of the other object.**
- **Static Electricity by Conduction (Contact): a charged object touches a neutral object, gives some charge to the neutral object.**
- **Static Electricity by Induction: inducing polarity or a surface charge because of electrons shifting.**

# Creation of static charge by friction



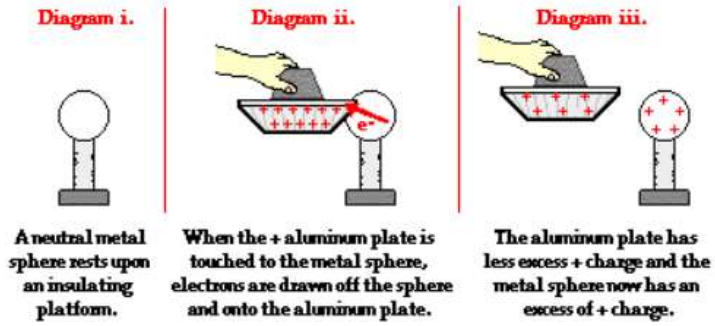



Before combing the hair, the comb (insulator) and hair are electrically-neutral.

After combing the hair, comb stripped electrons from the hair.

Comb = negatively-charged
Hair = positively-charged

## Charging a Neutral Object by Conduction



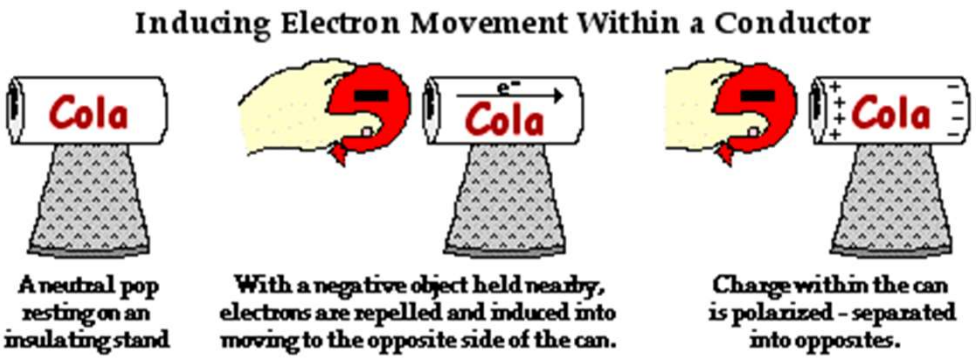
## Creating static charge by induction

"Inducing" a surface charge on a neutral object by bringing a charged object close to it.

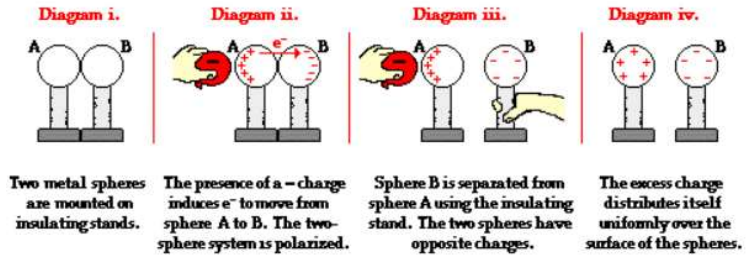
- No electrons are lost or gained by the charged object.
- Object remains electrically neutral.

Atoms on the surface become ***polarized.***

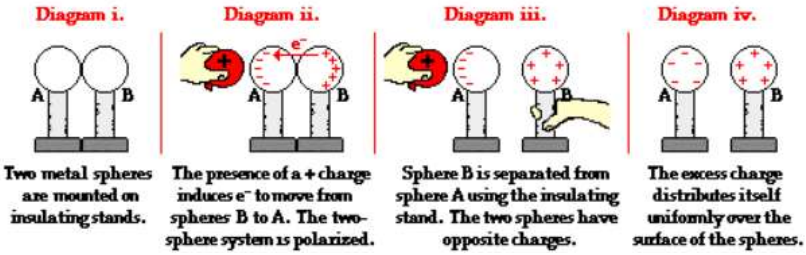
- Electrons in the atoms on the surface will shift toward positive charges or shift away from negative charges.



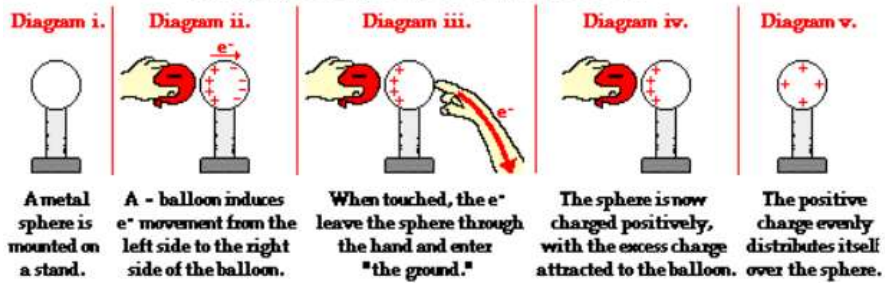
## Charging by Induction




## Charging by Induction




## Charging a Single Sphere by Induction



## Static Discharge

If excess static charge on an object is given a path to leave the object, it will quickly move, creating a spark and a shock

# Coulomb's Law

How strong is the force of electrical attraction/repulsion?

## Four Fundamental Forces

1. Strong force
2. Weak force
3. Electromagnetic force
4. Gravity

## Coulomb's Law

*The electrostatic force between charged particles is proportional to the product of the charges and inversely proportional to the square of the distance between the charged objects.*

- Electrostatic force is a ***mutual force*** (equal and opposite regardless of charge differences)
- Electrostatic force can be attraction or repulsion.
- The force is 10-billion, billion times greater than the attraction force of gravity.

## Coulomb's Law

$$F = k \cdot \frac{q_1 \cdot q_2}{d^2}$$

Proportional to product of charges

Inversely proportional to distance squared

$q_1$ = charge on object 1 (C)
$q_2$ = charge on object 2 (C)
d = distance between charged objects
k = electrostatic constant, $9.00 \times 10^9 \, N \frac{m^2}{C^2}$
F = attraction or repulsion force (N)

$$F = k \cdot \frac{q_1 \cdot q_2}{d^2}$$

Proportional to product of charges

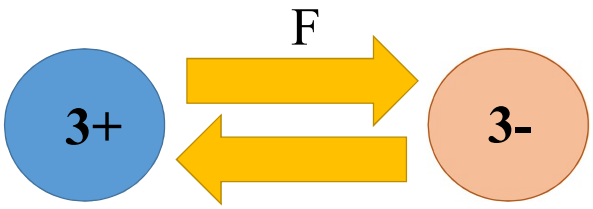
Charges are multiplied together.

When **opposite charges attract**, F is NEGATIVE.
The work is decreasing the distance between the opposite charges.

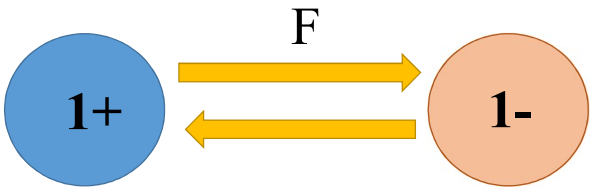
When **like charges repel** each other, F is POSITIVE.
The work is increasing the distance between the like charges.

## Magnitude of Charges

- Greater the product of charges, stronger force
- Lesser the product of charges, weaker force



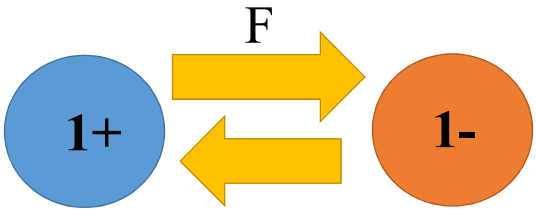

Greater charges, stronger force.




Lesser charges, weaker force.

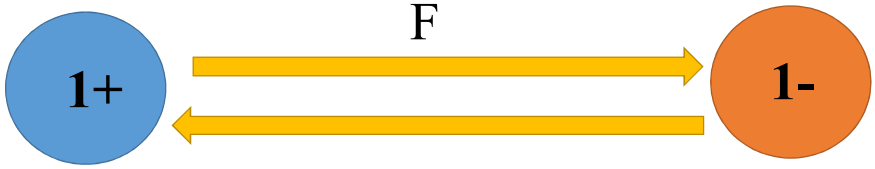
## Distance Between Charges

- Closer together, stronger force
- Farther apart, weaker force




Very close together, stronger force.

Very far apart, weaker force.



## Coulomb's Law vs. Universal Gravitation

$$F_e = k_e \frac{q_1 q_2}{d^2}$$

*q*: electric charge (+ or -)

$k_e = 8.99 \times 10^9 \ \mathrm{N \cdot m^2 / C^2}$

$$F_g = G \frac{m_1 m_2}{d^2}$$

*m*: mass (+)

$G = 6.67 \times 10^{-11} \ \mathrm{N \cdot m^2 / kg^2}$